

## **Waste Inspection Tomography (WIT) A Status Report on DOE Testing**

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### **Introduction**

With more than \$6M in development contracts for commercialization, from the U.S. Department of Energy (DOE contracts: DE-AC21-93MC30173, DE-AC21-96MC33127, and 96-RCI-09) plus an additional BIR cost-sharing investment of nearly \$1M, BIR has successfully demonstrated Computed Tomography (CT) characterization of nuclear waste drums. BIR has used CT as well as Digital Radiography (DR) for Nondestructive (x-ray) Examination (NDE) and Active & Passive CT (A&PCT) for Nondestructive (gamma) Assay (NDA) of nuclear waste drums. NDE defines the drum matrix (content) whereas NDA identifies and quantifies the gamma isotopics (radioactivity) within a drum. This BIR development applies to Low Level (LL), Transuranic (TRU, medium level radioactivity), and Mixed Waste (MW) drums that contain toxins (e.g. heavy metal) and radioactivity.

Between, 1993 and 1995, BIR developed and manufactured a mobile drum scanner. This development produced a production design of a self-sufficient semi-trailer called Waste

Inspection Tomography (WIT). The picture at the right shows the WIT trailer deployed at BIR with a drum being forklift loaded. In 1996, WIT successfully completed field tests at a number of interim waste drum storage sites across the U.S. These sites include DOE's Argonne National Laboratory (ANL), the Lawrence Livermore National Laboratory (LLNL), the Rocky Flats Environmental Technology Site (RFETS), the Idaho National Environmental and Engineering Laboratory (INEEL) and Babcock and Wilcox (B&W) in Lynchburg. A BIR company, WITCO (Waste Inspection Technology Company) currently provides mobile in-field commercial services as WIT operators for government and private customers requiring WIT NDE and NDA of nuclear waste drums.



During 1997, WIT successfully participated in a number of DOE sponsored blind tests including a Performance Demonstration Program (PDP), a Rapid Commercialization Initiative (RCI) and the Characterization Evaluation Program (CEP) designed to evaluate WIT characterization performance relative to DOE specified Waste Acceptance Criteria (WAC). WITCO is a member of the TRUtech team of commercial companies selected by the DOE to participate in a DOE program that will approve TRUtech team processes, including WIT. These processes are designed to characterize TRU waste drums destined for permanent disposal at DOE's Waste Isolation Pilot Plant (WIPP) in Carlsbad, NM. Approval of WIT and the TRUtech team by DOE and the U.S. Environmental Protection Agency (EPA) for TRU waste certification is expected after an audit at DOE's Nevada Test Site (NTS) before WIPP officially opens in May of 1998. In 1998, BIR and WITCO plan to purchase the first WIT trailer from DOE and provide a commercial WIT service to DOE for nuclear waste drum characterization to fulfill the main goal of these DOE contracts.

## Objectives

Advanced WIT NDE radiographic imaging techniques like DR and CT with an 18-bit solid-state 2 MeV linear detector array are designed for excellent contrast and 3-dimensional (volumetric) spatial resolution. This is not achievable with other baseline methods like 2-dimensional 8-bit real-time radiography (RTR) systems. Using 2 MeV, WIT can image drums as large as 110 gallons containing both light and dense materials such as combustibles, metals, sludge, cement, and compacted waste. WIT's NDE throughput is less than 15 minutes for full drum CT or 1 minute for full drum single view DR. The higher density wastes can not be imaged by RTR with 450 kV or less energy considered the current baseline approach for imaging 55 gallons drums containing low density waste.

Advanced WIT NDA with A&PCT provides gamma assay capability using Germanium detection for a variety of drum sizes and matrices without prior calibration by suspect drum content. WIT A&PCT was originally developed by the Lawrence Livermore National Laboratory (LLNL). BIR has acquired a commercial license for the copyrighted A&PCT reconstruction code from the University of California. WIT A&PCT corrects for the 3-dimensional attenuation map of each drum in real-time. Therefore Acceptable Knowledge (AK) or apriori knowledge of the drum's matrix, isotopes, and isotope gram amounts is not required by WIT. Whereas characterization with a baseline NDA technique like Segmented Gamma Scanning (SGS) requires AK and pre-calibration based on content. In 1998, WIT NDA and NDE throughput together is expected to be about 1 drum per hour.

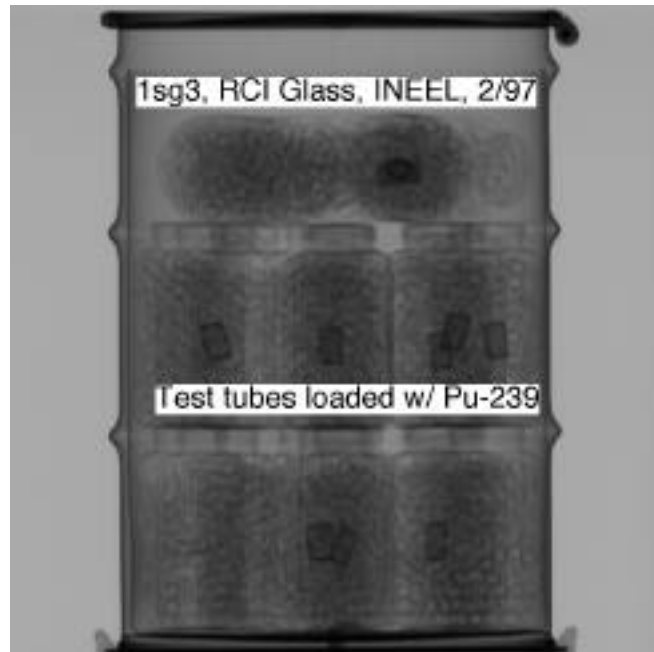
WIT 3-dimensional NDE/NDA CT volume rendering with rotational cinematic rotation of drum cut-aways with surface shaded displays can provide the reviewer with spatial orientation of both the matrix and radioactivity within the drum. This WIT capability provides a safe noninvasive method of verifying drum content without opening and repackaging a radioactive drum. The cost savings for CT volume rendering a drum vs. invasive repackaging in a remote handled glove box provides about a 20:1 cost savings. CT volume rendering is nearly \$500 per drum at 2 drums per hour whereas remote handled nuclear waste repackaging is nearly \$10,000 per drum at 2 drums per week. Remote handled drum repackaging has been the baseline technique to verify x-ray findings. WIT complies with the DOE TRU WAC for NDE/NDA. The following bullets summarize WIT:

- WIT is mobile and does not require new fixed facility construction or new personnel
- WIT characterization techniques can save DOE greater than \$390M
- WIT can examine all drum sizes, liners, and shielding including steel pipes and lead
- WIT can inspect all drum matrices from low density combustibles to high density cement
- WIT drum capacity is up to a 110 gallon volume each weighing up to 1,600 lb.
- WIT assay capability is 60 nCi/gm up to 200 gm (experienced from 0.1 to 70 gm Pu-239)
- WIT does not need AK(apriori or acceptable knowledge)or calibration by matrix/isotopics
- WIT has 5 networked computers and 9 axes of motion with drum rotation and elevation
- WIT is electrically self sufficient with an 80 kW diesel generator or supplied shore power
- WIT has self-sufficient communications with cell or shore; phones, faxes, and modems
- WIT external interfaces are fire/intruder alarms, LAN (WWIS), phone, and electrical.
- WIT can store 400 liters liquid Nitrogen, 100 gallons diesel fuel, & 20 gallons water.
- WIT is a 2 man operation with 2 days required for setup and tear down
- WIT throughput can be as great as 50 drums per day (for 3 view DR and drum tilt)
- WIT drums are site fork lift loaded with clean swipe tested drums or drum overpacks
- WIT output is VHS tape, DAT tape, CD-ROM, Hard Copy, photos, and LAN/e-mail
- WIT has 3 axles, weighs 87,000 lb., has 12 tons radiation shielding is 8.5'x60'x13.5'
- WIT has a radiation exclusion zone (36'x120'), safety interlocks, and monitoring systems
- WIT has a 2 mR/hour radiation limit for the 2 MeV Linatron source at exclusion fence line
- WIT includes fire suppression , intruder, positive air pressure, rad., and oxygen alarms
- WIT has a NEPA categorical exclusion and DOE approved documentation and procedures
- WIT NDE/NDA complies with the WAC for TRU waste drum disposal at WIPP

## Sample Results of WIT NDE

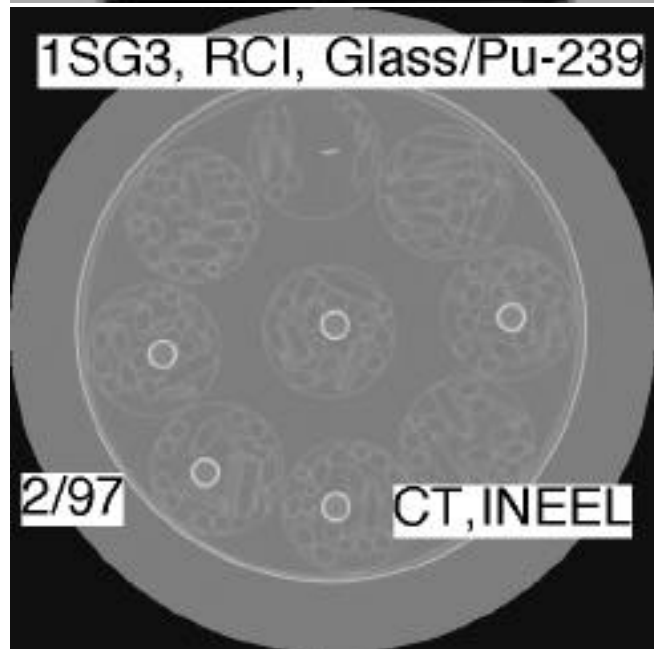
### Digital Radiography

WIT 2 MeV DR, 60 second scan of a 55 gallon drum of surrogate glass test tubes in plastic jars with Pu-239 loading indicated as the denser larger vials DR scanned by WIT during RCI field testing at INEEL in February 1997. The image has a matrix of 896 x 900 pixels with a resolution of about 1 mm.



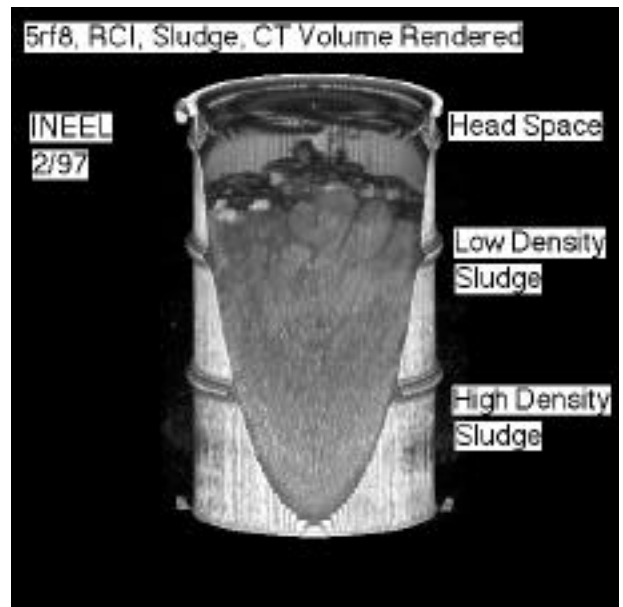
### Computed Tomography

WIT 2MeV CT scan of glass drum above showing the Pu-239 loading vials among glass test tubes. This scan is a 10 mm slice and had a 30 second scan time. This image is 512 x 512 matrix with a resolution of about 1 mm.



### CT Volume Rendering

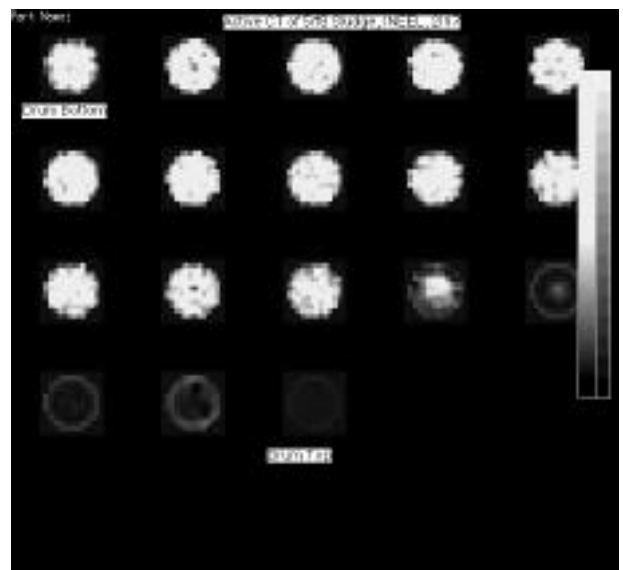
WIT X-ray CT Volume Rendering of a 55 gallon drum of real TRU waste sludge. This image includes 90 CT slices each 10 mm thick and requiring 30 seconds for data acquisition. (An 8 second slice is also possible with WIT parallel processing for a 1024 x 1024 image with a lower density matrix such as combustibles.) This sludge volume rendering is a 512x512x512 pixel image. Note that a image indicates higher density more uniform sludge below the lowest drum rib and lower density lumped sludge above the lowest drum rib. This WIT image was acquired at INEEL during RCI testing in February of 1997.



### **Sample Results of WIT gamma NDA**

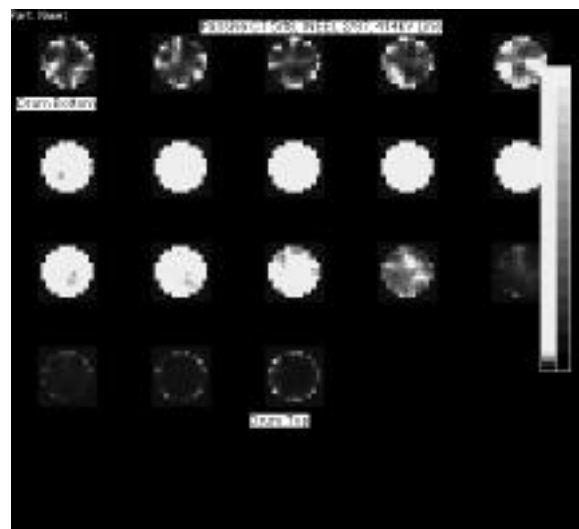
#### ACT of a Sludge drum

This is a WIT Active CT (ACT) 18 slice map of the mass attenuation coefficients each 50 mm thick of the volume rendered sludge drum in the NDE section of this web site. Note that the density of the sludge slightly increases toward the bottom of the drum. This is the same drum as shown above with X-ray CT volume rendering.



#### PCT of a Sludge Drum

This is a WIT Passive CT (PCT) 18 slice map of gamma activity at 414 keV of the above sludge drum. Note that the bottom 5 slices are cold compared to the remaining upper slices of the sludge drum. This 3 dimensional map shows that the lower (below the lower drum rib) higher density sludge is not as radioactive as the top lower density sludge which has the most radioactivity. This PCT NDA information is consistent with the NDE x-ray CT volume rendering data showing physical density differences described above which is this same drum.



### DOE Blind Testing and WIT NDA Test Results

During 1997, WIT was involved in a series of blind tests to determine and demonstrate NDA accuracy and precision for TRU waste assay using WIT's A&PCT assay technique. The following table summarizes the WIT results for precision (or uncertainty) only. The TBA (To Be Announced) WIT results are not yet available for public disclosure because other NDA systems (other than WIT) are yet to be blind tested such that the real answers have thus far not been disclosed. However, BIR has been informed that WIT has passed both the accuracy and precision (uncertainty) testing for the first 4 CEP tested drums listed below. The test results from the last two PDP drums have not yet been disclosed as of this publication date and are not expected to be released to the public until March of 1998.

#### Waste Inspection Tomography (WIT) Assay Blind Test Results From October, 1997 at INEEL/RWMC, BIR Reported 10/28/97

TRU Drum #	1	2	3	4	5	6
Drum ID #	CEPRF-20	CEPSG-6	CEPSG-9	CEPRF-11	PDP-003	PDP-001
Content Code	480	409	442	3	Cycle 4	Cycle 4
Matrix	Leached Metals	MSE Salts	Raschig Rings	Sludge	Combustibles	Zero
Net Weight (kg)	109	68	64	140	44	0.5
# of Replicates	8	8	8	7*	6**	6**
Mean Grams Pu-239 measured	TBA	TBA	TBA	TBA	TBA	TBA
Standard Deviation	TBA	TBA	TBA	TBA	TBA	TBA
Variance†	TBA	TBA	TBA	TBA	TBA	TBA
% Count (assay) Uncertainty ***	0.82	1.5	4.4	3.3	2.7	1.5
% Total Uncertainty ****	5.1	5.2	6.7	6.0	5.7	5.2

\* The eighth replicate was 2x the mean value of the other 7 measurements of Pu-239 and was acquired during a liquid Nitrogen fill cycle while the HPGe dewar was filling. This 8th value was not used for this table because the HPGe was warming up during data collection.

\*\* The PDP cycle only requires 6 replicate measurements.

\*\*\* = % of Standard Deviation divided by the Mean

\*\*\*\*= Root Mean Squared (RMS) of an estimated 5% Systematic Error plus % Count Uncertainty without bias correction

† Variance= Standard Deviation Squared

**Notes: 1. These tests measure Transuranic (TRU) Waste Drum Nondestructive Assay (NDA) Accuracy and Precision using Active and Passive Computed Tomography (A&PCT Rev. 1.3) measurements taken onboard the WIT trailer.**

**2. These tests are part of the Capability Evaluation Project (CEP) from DOE EM-50 and the Performance Demonstration Program (PDP) from the DOE CAO for the National TRU waste Program**

**3. Test results are without, lump, error, or bias correction, and without calibration by matrix, gram amount, or isotope.**

**4. Typical assay time per replicate was 19.8 hours using one 100% efficient HPGe detector and 1.4 mCi of Ho-166.**

**5. Typical computer analysis and reconstruction time per replicate was less than 1 hour in parallel with the next replicate data collection on a 66 MHz Pentium PC using an assumption of weapons grade Pu for isotopic ratios, alpha activity, and thermal analysis.**

### **The Future of WIT with TRUtech-WITCO Team Services**

TRUtech along with its partner WITCO (a BIR company) and Team members APNEA, Inc., Entropy Inc., ECO, and Bartlett Services, Inc. have entered into a cooperative agreement with the Department of Energy (DOE) Albuquerque Operations Office associated with the DOE Mobile Systems Approval Program. The major objective of the agreement is to obtain DOE approval for a collection of mobile (trailer mounted) Team services and processes that will allow for the permanent disposal of DOE Transuranic (TRU) waste at the Waste Isolation Pilot Plant (WIPP) near Carlsbad, NM, scheduled to open in the Spring of 1998. WIPP is an underground salt formation mined for permanent TRU waste drum disposal. DOE's TRU waste results from over 50 years of nuclear weapons development and includes greater than 600,000 TRU drums currently residing at temporary DOE retrievable storage sites across the U.S. that need to be disposed of at WIPP. The TRUtech -WITCO Team offers DOE distinct capabilities and relevant experiences using existing, proven, and innovative technologies that place the TRUtech-WITCO Team well ahead of commercial competition. The Team has:

- existing commercial mobile equipment for TRU drum characterization and processing
- successful field tested characterization experiences with Head Space Gas (HSG), and Resource Conservation and Recovery Act (RCRA) heavy metals analysis and Non-destructive x-ray Examination and with gamma and neutron Assay (NDE/NDA) of benign and high-density waste
- successful waste drum processing capability for drum repackaging, sampling, coring, and TRUPACT-II loading for drums transport to WIPP
- experienced staff for quality assurance, safety, health physics, and data management.

The Team's technologies have been developed and supported over the past 6 years by DOE Environmental Management (EM) and others including; EM-50, EM-30, DOE National Laboratories including Livermore (LLNL), and Oak Ridge (ORNL), Idaho (INEEL), the Environmental Protection Agency (EPA), various States, Corporations, and Universities across the United States and France. As industrial technology and service providers, the Team has a DOE marketing focus that addresses all DOE mission objectives regarding the mobile field processing of TRU nuclear waste destined for WIPP. The TRUtech-WITCO Team provides the DOE processing capability for:

- small DOE storage sites that do not have processing capabilities for TRU waste
- supplementing large DOE sites that lack some processes
- supporting, in parallel, large DOE sites for increased process throughput
- processing difficult waste matrices (i.e. dense) that conventional approaches can not
- long term services including the DOE EM ten year plan and beyond
- drum pre and post treatment processing of waste
- the processing of any suspect DOE TRU waste planned for WIPP disposal
- generation, communicating, & archiving of safety, quality, procedure, and data reports

For more information about TRUtech-WITCO Team member services please contact the Team Managing Director and TRUtech President, Mr. Gerald Sterier at the Team project office, 501 W. Broadway Suite 300, Idaho Falls, ID 83402, phone (208) 542-0142 or e-mail Gerry at <ggs@ida.net> or the WIT Program Manager and WITCO President, Mr. Richard Bernardi, at BIR, Inc., 425 Barclay Blvd., Lincolnshire, IL 60069, phone (847) 634-6425 ext. 114, or e-mail Dick at <bernardi@interaccess.com> or visit BIR's Web site at <www.bio-imaging.com>.